

The geochemical signal of the provenance of ice-rafted deposits and ice sheet dynamics

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Ice sheets are important components of the climate system.

Their high albedo leads to a positive cooling feedback, and their presence affects atmospheric and oceanic circulation.

Understanding the temporal record of ice sheets in the past and how they correlate to other climate-sensitive processes are important to understanding the vulnerability of ice sheets in a warming world. The distribution of ice-rafted detritus in marine sediments has been used in the polar oceans to provide significant insights into ice sheet behavior and processes that control climate conditions. A key element for understanding ice sheet interactions in the climate system is identifying the major sources of ice-rafted detritus. I will review some examples of the application of radiogenic isotope provenance studies of glaciogenic marine sediments. Because of the fortuitous patchwork distribution of continental terranes with variable geologic age and history, radiogenic isotopes are powerful tracers of sediment provenance that can provide important clues about past ice sheet behavior. In favorable cases application to marine sediments allows developing a precise time line of ice sheet behavior that can be integrated with evidence for paleoclimate and paleoceanography changes. Additionally ocean sediment archives tend to have relatively continuous sediment accumulation, so although they are separated from the more direct continental evidence, they provide an important complement to the study of land-based glacial features.

There is a wide array of fruitful approaches to geochemical provenance of glaciogenic marine sediments. Because sediments produced from glaciers tend to be dominantly from strongly mechanical weathering regimes, the degree of chemical alteration is a good indication of the abundance of recycled sedimentary sources. Approaches that use bulk sediments have the advantage of providing an average of the contributing sources and the disadvantage of providing a mixed signal. Approaches that use measurements of individual grains have the advantage of separating multiple source contributions and the disadvantage of being much more costly and time-consuming. The combination of bulk-sediment and individual grain approaches is preferred. A combination of petrographic and geochemical approaches helps to mitigate the inevitable biases of each individual approach, although most geochemical approaches are biased against detecting mafic contributions.

²³⁶U in seawater – contaminant and tracer

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U-236 is generated from ²³⁵U by the neutron flux of a nuclear explosion or power plant. Resulting ²³⁶U/²³⁸U ratios from such processes can be as high as 5×10^{-3} [1] and up to 8 orders of magnitude higher than expected theoretically for the natural environment. In contrast, ²³⁸U/²³⁵U ratios vary by only 4 orders of magnitude between weapons grade and residual depleted uranium. U-236 is therefore a more sensitive tracer of the presence of nuclear contamination. In seawater, the conservative behaviour of uranium means that this tracer may provide information not only about contamination, but about ocean mixing and advection away from point sources of such contamination.

U-236 has not frequently been measured in the natural environment, but most studies to have done so rely on accelerator mass spectrometry (AMS) to achieve the high abundance sensitivity required to accurately assess the ²³⁶U/²³⁸U ratio. In this study, we demonstrate the use of ICP mass spectrometry (with a large-geometry Nu-Instruments 1700 MC-ICP-MS) to measure ²³⁶U/²³⁸U ratios as low as 10^{-8} . Although this detection limit is not as low as that of AMS, the ICP approach allows measurement on significantly smaller samples (≈ 200 mL of seawater) and for more routine sampling and analysis.

We present measurements on a suite of 30 seawater samples collected from the upper 50 m of the water column offshore the Fukushima power-plant in the months immediately following the disaster at that plant. The samples were collected from the RV KOK during a cruise (June 4-19 2011) sponsored by the Gordon and Betty Moore Foundation, and are set in the context of Cs isotope results. A wide range of other contaminant radionuclides will also be measured on seawater samples from this cruise, enabling the release of ²³⁶U from the Fukushima plant into the marine environment to be well constrained, and the relative impact of atmospheric versus hydrographic routes to the ocean to be assessed. This case study will also provide an assessment of the future use of ²³⁶U as a tracer of ocean contamination and transport.

[1] S.F. Boulyga and K.G. Heumann, 2006, *Journal of Environmental Radioactivity* **88** 1-10.